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14. ABSTRACT Previous models used to predict the likelihood of MIC were based on numbers of specific types of organisms, often determined by liquid culture of planktonic bacteria (not archaea). It was agreed that this procedure was not reliable. For oil field systems, more modern models are based on qPCR and cell-specific rates of SRP ad methanogens.						
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THIS MONTH: CORROSION IN THE WATER AND WASTEWATER INDUSTRY

JUNE 2012

# MMP MATERIALS PERFORMANCE

CORROSION PREVENTION AND CONTROL WORLDWIDE

## Studying the Effects of Galvanic Corrosion on Lead Levels in Drinking Water

Extending the Life of Iron Pipe in Corrosive Soils

Fifty-Year History of Polyethylene-Encased Iron Pipelines

Low-Maintenance Coating Systems

Special Features:

*CORROSION 2012 Plenary Lecture: Knowledge Transfer from Experienced to Novice Engineers*

*CORROSION 2012 Recap*



**NACE**  
INTERNATIONAL



# CORROSION 2012 RECAP

## 10th Annual Golf Tournament Features a View of the Rockies

A dedicated group of golfers and NACE Foundation supporters came together on Sunday during the Darrel Byerley Memorial Golf Tournament, held at Stonebridge Golf Club in West Valley City, Utah, to tee off a gorgeous day of golf at CORROSION 2012. Thanks to the support of our top sponsors—Mach Industrial Group; Howco Metals Management, P.A., Inc.; and Spectrum Pipeline Services—along with a host of other sponsors, donors, participants, and volunteers, the tournament produced net proceeds of more than \$15,000 to benefit the Foundation's programs and scholarships. The Foundation would like to recognize Co-Chairs Gene Lawson and Keith Perkins, as well as other committee members and volunteers, for giving their time and energy to make this tournament a success. Visit [www.nace-foundation.org/events](http://www.nace-foundation.org/events) for a complete listing of sponsors, winners, and photos from the tournament.

## Avoiding Premature Coating Failures Is Topic of Tutorial

In this workshop, "How to Avoid Premature Coating Failures," taught by Mike O'Brien (MARK 10 Resources Group), participants were shown numerous examples and photos of actual coating failures on steel and concrete and were presented with practical knowledge to reduce or avoid problems with coatings that lead to these untimely failures.

## New Forum Addresses Microbiologically Influenced Corrosion

In a new forum, "State-of-the-Art Approach for MIC Quantification, Detection, and Mitigation," chaired by Torben Lund Skovhus (DTI Oil & Gas) and Brenda Little,



The Opening Reception sponsored by Carboline Co. and NACE featured refreshments and fellowship.

FNACE (U.S. Naval Research Laboratory), presenters from DNV, ConocoPhillips, Maersk Oil, the University of Oklahoma, and ANR Pipeline shared the steps they take when microbiologically influenced corrosion (MIC) is suspected. Discussion points included determining whether environmental conditions are conducive to microbial growth and metabolism, techniques for analyzing samples and the information they provide, identifying the root cause of MIC, ascertaining risk, and mitigation strategies. See the article on p. 91 to read more about this discussion.

## NACE and ACCE Host China Forum

For the first time, NACE and the Association of Chinese Corrosion Engineers (ACCE) partnered to present the 2012 NACE/ACCE China Forum, designed to bring together Chinese corrosion experts from all over the world. This half-day forum included technical presentations and activities in both English and Chinese and covered a variety of corrosion-related topics including pipeline integrity management, microbiologically influenced corrosion (MIC), oil and gas field corrosion, and

electrochemical probes. Chaired by Xihua He (Southwest Research Institute), presentations included "Electrochemical Imaging for Localized Corrosion—From Laboratory to Industrial Fields," by Chang-Jian Lin (State Key Laboratory of Physical Chemistry of Solid Surfaces, College of Chemistry and Chemical Engineering at Xiamen University); "Challenges Facing Chinese Corrosion Engineers in Pipeline Integrity Management," by Qingshan Feng (manager of the Pipeline Integrity Management Center, PetroChina Pipeline Co.); "Probe and Practice in Some Frontier Issues on Corrosion of Oil Well Tube and Transmission Pipeline," by Minxu Lu (Corrosion and Protection Center, University of Science and Technology Beijing); "Recent Advances in Microbiologically Influenced Corrosion (MIC)," by Tingyue Gu (professor with the Department of Chemical & Biomolecular Eng., Institute for Corrosion and Multiphase Tech. at Ohio University); "Overview of NACE MR0175/ISO 15156," by Robert Badrak (Weatherford, Co.); and "Corrosion Research Progress and Challenges for Materials in LWR in China," by En-Hou Han (Institute of Metal Research [IMR], Chinese Academy of Sciences).

## Opening Reception

Again this year attendees enjoyed drinks and hors d'oeuvres at the Opening Reception, a conference kick-off tradition that provides everyone with the opportunity to catch up with old friends and make new contacts after a day of administrative and technical meetings. NACE thanks Carboline Co. for sponsoring this event, which featured lively music, wonderful food, and fellowship.



Golfers enjoyed beautiful views and weather during the Foundation's Darrel Byerley Memorial Golf Tournament during CORROSION 2012.

#### NACE Student Poster Session Winners

To encourage students to become active in NACE International and to present the results of their work to the membership, the NACE Research Committee sponsors a Student Poster Session at each CORROSION conference. Students may enter posters in one of three categories: (1) the Mars Fontana category for the field of corrosion engineering; (2) the Harvey Herro category for the field of applied corrosion technology; and (3) the Marcel Pourbaix category for the field of corrosion science. First-, second-, and third-place prizes are awarded in each category, as well as a Best Undergraduate Poster prize. Thanks to BP for providing financing for the prizes, sponsoring lunch for all the participants and winners, and printing the *Student Poster Session Abstracts* book. A list of this year's winners follows.

##### Huang Lin

The Ohio State University

##### First Place, Mars Fontana Category

"Correlation of Field Exposure and Accelerated Laboratory Testing of Ag and Cu Using Ozone, Ultraviolet Radiation, and NaCl"

##### Joseph Fernandez

University of South Florida

##### Second Place, Mars Fontana Category

"Effects of pH and Temperature on the Initiation of Stress Corrosion Cracking in High Strength Stainless Steels for Prestressed Concrete"

##### Elisabeth Schwarzenböck

University of Bourgogne

##### Third Place, Mars Fontana Category

"Microelectrochemical Behavior and Corrosion Resistance of Titanium Alloy Ti-6Al-4V in Chloride Containing Solutions"

##### Meng Tong

The Ohio State University

##### First Place, Harvey Herro Category

"In Situ Monitoring of Undercoating Corrosion Damage by Direct Optical Interrogation (DOI)"

##### Shokrollah Hassani

University of Tulsa

##### Second Place, Harvey Herro Category

"Flow Loop Studies on the Effect of a Light Oil Phase on CO<sub>2</sub> Corrosion and Inhibitor Performance"

##### Ivana Jevremovic

University of Belgrade

##### Third Place, Harvey Herro Category

"Top-of-the-Line Corrosion (TLC) Mitigation of Mild Steel in CO<sub>2</sub> Environment Using Corrosion Inhibitor Injected Within a Foam Carrier"

##### Mary Lyn Lim

University of Virginia

##### First Place, Marcel Pourbaix Category

"Experiments and Modeling of Intergranular Corrosion Penetration in AA5083"

##### Omar Lopez-Garrity

The Ohio State University

##### Second Place,

##### Marcel Pourbaix Category

"The Corrosion Inhibition of Aluminum Alloy 2024-T3 by Aqueous Silicate, Molybdate, and Praseodymium Species"

##### Liu Cao

The Ohio State University

##### Third Place, Marcel Pourbaix Category

"Corrosion and Cracking of Carbon Steel in Fuel Grade Ethanol—Roles of Oxygen, Potential, and Chloride"

##### Shaghik Abolian

California Polytechnic University

##### Best Undergraduate Poster

"Pack Cementation Coatings on Metallic Substrates for Corrosion Protection"



Left to right: James Burk, BP, with Harvey Herro Category winners Shokrollah Hassani, Meng Tong, Ivana Jevremovic, and Student Poster Session Chair Joseph R. Kish.



Left to right: Burk with Mars Fontana Category winners Joseph Fernandez, Huang Lin, Elisabeth Schwarzenböck, and Kish.



Left to right: Burk with Marcel Pourbaix Category winners Omar Lopez-Garrity, Mary Lyn Lim, Liu Cao, and Kish.

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#### New Forum Addresses Microbiologically Influenced Corrosion

On Sunday, March 11, as part of CORROSION 2012, the forum, "State-of-the-Art Approach for MIC Quantification, Detection, and Mitigation," was held for the first time. The forum-meeting format facilitated open discussion without the necessity of submitting publishable papers, permitting speakers to present the most current information about a specific topic.

Torben Lund Skovhus, DTI Oil & Gas (Aarhus, Denmark), and Brenda Little,

FNACE, U.S. Naval Research Laboratory (Stennis Space Center, Mississippi), organized the forum with the help of NACE International staff. The following six recognized authorities on the subject of MIC (in alphabetical order by last name) were invited to contribute: Scott Campbell, independent consultant (Houston, Texas); Rick Eckert, DNV (Dublin, Ohio); Gary Jenne- man, ConocoPhillips (Bartlesville, Oklahoma); Jan Larsen, Maersk Oil (Copenha-



gen, Denmark); Joseph Suflita, University of Oklahoma (Norman, Oklahoma); and Tim Zintel, ANR Pipeline (Troy, Michigan). Invitees were asked to address the following question: "If you suspect MIC, what five things do you consider and measure?"

The presenters emphasized the need for evaluating the overall situation to eliminate other potential causes of corrosion before beginning any assessment of MIC. Since MIC does not produce a unique corrosion morphology, it is essential that samples are collected and examined carefully. Samples could include water (e.g., production fluid), solids (e.g., materials from pig runs), and pipe spools or corrosion coupons. All speakers stressed the necessity for collecting samples that could be interpreted (i.e., samples that had not been disturbed or compromised by collection and storage). Sample preservation at the time of collection determines the types of tests that can be conducted.

Eckert focused on the necessity of relating macro-environmental conditions to the sub-micron before evaluating the possibility of specific MIC mechanisms. He defined the following five possible roles for microorganisms associated with corrosion products in causing the corrosion—exclusive, primary, contributory, non-contributory, or unknown.

Jenneman reiterated the importance of collecting multiple types of data from multiple sources (water, solids, coupons, etc.) and ensuring that the data were consistent with the final interpretation.

Suflita described an idealized sampling scheme that included traditional culture techniques, molecular analysis, and metabolic profiling. The procedure had been tested on the North Slope of Alaska and provided fundamental information for understanding MIC at the field site.

Campbell described a monitoring system for a Type 316L stainless steel (UNS S31603) drinking water distribution system that measured open circuit potential (OCP) as a function of time. Ennoblement of OCP was related to biofilm formation using pyrosequencing to determine community structure and polysaccharide analysis to determine the amount of extracellular polymeric substances on the surface. Environmental scanning electron microscopy (E-SEM) coupled with energy dispersive x-

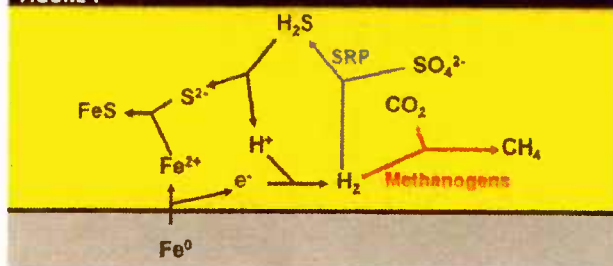
ray analysis was used with x-ray diffraction to characterize surface deposits. Biocides (concentration and frequency) were evaluated based on their ability to control OCP below the pitting potential for this crevice corrosion-prone material.

Zintel described a monitoring system for an 8-in (203-mm) diameter pipeline that included liquid culture and a bioprobe—coupons that could be removed periodically and examined with scanning electron microscopy to determine relationships between localized corrosion and microorganisms. Both techniques were used to optimize biocide additions.

Larsen described an approach to MIC risk assessment using a model that has been successfully utilized in the Danish sector of the North Sea to prevent MIC failures. Model calculations are based on numbers of MIC-causing microorganisms (in this case, sulfate-reducing prokaryotes [SRP] and methanogens, Figure 1) measured by quantitative polymerase chain reaction (qPCR), stoichiometries for the electron flow at the metal surface, and empirically determined cell-specific reaction rates. The current model transforms microbiology numbers obtained by qPCR into a traffic light system for MIC risk.

A general comment from the audience was related to the continued dependence on microbiological data to interpret and predict MIC. Some of the discussion items were topics that have been debated for decades. One such topic was the matter of using planktonic (free swimming) counts vs. sessile (attached to surfaces) counts for establishing numbers of particular types of corrosion-causing organisms. The consensus continues to be that planktonic samples are not ideal since the microbial analysis can lead to a severe misinterpretation with respect to the MIC problem. Planktonic numbers are much lower than sessile numbers. However, in-house work at Maersk Oil has shown that the relationship between sessile and

FIGURE 1



MIC model (based on qPCR assays) driven by SRP and methanogens. Source: J. Larsen, et al., "Consortia of MIC Bacteria and Archaea Causing Pitting Corrosion in Top Side Oil Production Facilities," CORROSION 2010, paper no. 10252 (Houston, TX: NACE International, 2010).

planktonic populations is strongly influenced by flow rates, production history, local temperature, use of chemicals, and the degree of seawater breakthrough in the oil field. Larsen suggested that, when possible, both populations should be collected and examined to establish potential relationships.

Questions and comments from the audience were related to the cost/benefit of switching from culture-based to molecular-based techniques for decision making (e.g., biocide addition, pigging, etc.). It is clear that all monitoring techniques work as long as the operator understands the plant/system. The authorities agreed that the outcome of the molecular analysis highly depends on the primer set used to obtain the data.

Previous models used to predict the likelihood of MIC were based on numbers of specific types of organisms, often determined by liquid culture of planktonic bacteria (not archaea). It was agreed that this procedure was not reliable. For oil field systems, more modern models are based on qPCR and cell-specific rates of SRP and methanogens.

The forum was well attended, with ~120 delegates. It was an excellent kick-off to a busy week that featured two full days of symposia covering MIC—Microbiologically Influenced Corrosion, sponsored by Technology Exchange Group (TEG) 187X, and Control of Problematic Micro-Organisms in the Oil and Gas Industry, sponsored by TEG 286X. We hope to see many fellow NACE members at CORROSION 2013 in Orlando, Florida, where TEG 187X will be sponsoring the annual MIC symposium. —Torbin Lund Skovhus and Brenda Little, FNACE)